The *Story* Behind Your Soap

By EDWIN EARLE SMITH, Ch.E. IV

SOAP has become such a common article in every home of modern civilization that its applications and development have been overlooked. Few realize the importance it has attained in the widely diversified industries it has entered. Few recognize the vast difference in our soaps of today as compared with those of twenty-five years ago.

Soaps, more accurately termed detergents, have been developed to the point where their properties are as varied as their applications. Obviously there is considerable difference in the qualities of a soap used in washing the bristles in a hairbrush factory and that used on a "baby's tender skin". To meet special needs of any extremes, new detergents have been and will be developed.

Twenty-five years ago, most household soap was a soft, clay-like mass that left a gummy, slimy precipitation when used in "hard" water. It clogged pipes, discolored clothing, and made cleaning very difficult if not impossible. At first the chemists tried to improve the solvent (the water), but now they are working on the soap itself.

The chemistry of the various detergents is of one general type. Soap is the salt of an inorganic base and a fatty acid. In industry it is manufactured by the reaction of a fatty acid ester with a strong base such as sodium hydroxide or sodium carbonate. This reaction is similar to the formation of a weak base in inorganic chemistry, for example the preparation of ammonium hydroxide from ammonium chloride and sodium hydroxide:

$$NH_4Cl + NaOH = NaCl + NH_4OH$$

The fact that ammonium hydroxide does not ionize to a large extent causes this reaction to go to the right but not to completion, an equilibrium condition being reached. If it were possible to remove the ammonium hydroxide from this solution as it is formed, the reaction would continue to move to the right to restore the equilibrium condition.

In the soap-making reaction, or saponification, the reactants, a fatty acid ester such as olein, $C_3H_5(C_{18}H_{33}O_2)_3$, and sodium hydroxide react in chemical language as follows:

$$C_3H_5(C_{18}H_{33}O_2)_3 + 3NaOH = 3Na(C_{18}H_{33}O_2) + C_3H_5OH$$

The soap formed in this case, sodium oleate $(Na(C_{18}H_{33}O_2))$, is formed as a colloidal suspension in the glycerine and water in which the reaction takes place. The introduction of an electrolyte, such as sodium chloride, causes these extremely small particles to coagulate and percipitate in particles large enough to be easily removed. The reaction may thus proceed further to the right. This process is known as "graining" or "salting-out" the soap.

The oils and fats from which the esters are derived are complex compounds and mixtures, but consist mainly of stearin, palmitin, and olein. These are obtained from olive oil, cottonseed oil, cocoanut oil, and animal fats.

A soap is usually referred to as a compound with the structure R-COONa, where R- represents one of the hydrocarbon chains. The soap in the above reaction could be written $C_{17}H_{33}$-COONa which more plainly shows it to be a salt of an inorganic base and a fatty acid, and is very useful in explaining the cleansing properties of soap.

The physical chemist has advanced numerous theories on this property, but no one explanation is claimed to be the correct or the complete one.

Most theories have as their basis the molecular structure of the soap molecule. The long hydrocarbon chain, R-, is a solvent for oils and grease, while the other end of the molecule, -COONa, has properties of an inorganic compound that is soluble in water. If one molecule of soap were observed in solution with water as it flows over an oily surface, the long hydrocarbon chain would be seen to be the solvent in dissolving the oil into itself. The other end of the soap molecule, being soluble in water, stays in solution, pulling with it the R- chain and the dissolved oil as the water flows over the surface. This ability to hold oil and water simultaneously in solution explains its emulsifying properties. A solution of oil and water, when shaken after the addition of soap, will not separate. Such an artificial mixture is called an emulsion.

This theory explains the cleansing property of soap as applied to removal of oil and grease, but offers no clue to its ability to remove grit and soot. This property might be explained by the colloidal state of a soap solution.

Experiments indicate that a soap solution is a colloidal dispersion or suspension of the soap. The fact that the soap is curdled out of its solution by salt is good evidence of its colloidal nature. The colloidal chemist has shown that particles of colloidal size present a tremendous surface area, and usually the most important physical property of such an aggregation is its ability to adsorb an amazing quantity of other colloidal or molecular material. Therefore the colloidal suspension of a soap solution, when brought into contact with finely divided material such as grit, or soot, would absorb it into solution and wash it away.

The adsorbtive and emulsifying properties of soap make it a good detergent or cleaning agent. Yet, as mentioned before, soap has some very annoying characteristics. In an acid solution, a fatty acid is precipitated from the soap:

$$R\text{-}COONa + HCl = NaCl + \underline{R\text{-}COOH}$$

With water containing salts of the heavier metals (hard water), a slimy, insoluble soap is precipitated:

$$2R\text{-}COONa + CaCl_2 = 2NaCl + \underline{(R\text{-}COO)_2Ca}$$

Much research has been undertaken to discover methods of softening hard water to avoid these undesirable reactions. Sodium carbonate has been used with soap to precipitate the carbonates of the heavier metals in preference to these insoluble soaps. Other processes such as the Permutit process have proven successful in softening hard water on a large scale.

A new approach has been developed in recent years. Instead of trying to soften the water, the soap itself has been altered to escape these undesirable qualities.

The first noteworthy attempt to overcome this precipitation was the manufacture of "sulfated oil". Instead of being treated with a base, the fats or oils were treated with sulfuric acid. The resulting compound contained the long chain hydrocarbon in a positive radical, and hence was not subject to precipitation by the likewise positively charged metallic ions. This type of detergent was too low in cleansing value to displace the regular soap.

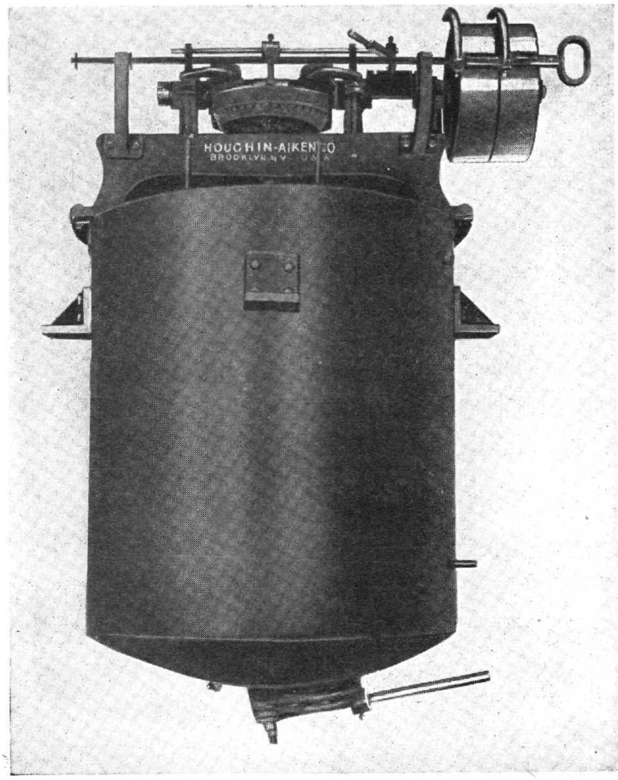
This new approach instigated intensive research, and led to discoveries which have proven to be very fruitful. The type of soap known as alkyl sulfates has become of particular importance. These are produced by three principle reactions: the fatty acid is reduced by hydrogenation to the corresponding alcohol:

$$R\text{-}COOH + 2H_2 = R\text{-}CH_2OH + H_2O$$

The alcohol is then treated with sulfuric acid to yield an alkyl acid sulfate:

$$R\text{-}CH_2\text{-}OH + H_2SO_4 = R\text{-}CH_2\text{-}HSO_4 + H_2O$$

The acid sulfate is then neutralized with a base such as sodium hydroxide to form a sodium alkyl sulfate.



Courtesy Houchin Machinery Co.

The Ingredients of the Soap are Mixed in This Soap Crutcher

These detergents exhibit an amazing resistance to precipitation in hard water. Investigation has shown the heavy metal alkyl sulfates to be even more soluble than the sodium salt. Different properties can be obtained by the use of different hydrocarbons. Characteristics of almost every soap can be duplicated by variation in the structure and the hydrocarbon base.

In the large scale production of soap, the fats or oils and alkali are combined in large, steam-heated kettles holding up to 300,000 pounds of mixture at one time. The material is allowed to react for two days, with steam bubbling through it. At the end of the period, the soap and glycerine mixture is "salted out". Several tons of common salt are used in the process. After it coagulates from its colloidal suspension and comes to the surface, the liquid remaining is tapped off and purified to obtain the valuable glycerine from the "spent lye" and other impurities. The soap is then dipped out, cooled, and allowed to solidify. Such curd soap contains glycerine, salt, lye, and other foreign substances and must be purified. The curd is mixed with brine, allowed to separate, the liquid removed, and the process repeated as often as is necessary. The final washing is done in water, the mixture heated, and again allowed to separate. The product is by this time very pure.

At this stage, the soap is liquid, and is run into

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frames to harden and "age". After trimming, stamping, and packaging, it is ready for the market.

Some products are given special treatment to vary their properties. Floating soap is made by beating air into the liquid mass. Laundry soaps and strong cleansing agents may contain free alkali such as sodium carbonate, borax, or pumice. Transparent soap is made by the addition of alcohol, glycerine, or sugar.

The majority of the people limit soap to its role as a cleansing agent. Few realize the vital part it plays in modern industry in uses unrelated to its cleansing qualities, but dependent on the same properties which give it these qualities.

The ability of soap to produce suspensions in water plays an extremely important part in the manufacture of waxes, rubber, artificial resins, and the like. A revolutionary type of paint recently developed owes its existence to soap. This paint, which eliminates noxious vapors, is quick-drying and noninflammable, consists essentially of synthetic resins and pigments held in a suspension of soapy water.

Modern high-speed machinery relies on lubrication. Many of the different kinds of greases and oils that go into all sorts of machinery contain soap as an essential ingredient. The addition of soap to petroleum has long been known to result in its solidification into a grease. The value of this characteristic is obvious: solids do not leak out of containers such as shaft openings, or spatter off rotating surfaces as readily as liquids. But even more important is the actual improvement in lubricating and wearing properties that soap imparts to oil. Recent developments in soap-base greases have produced lubricants which can function from sub-zero temperatures to the temperatures of the internal combustion engine with but slight change in viscosity.

Soap is used in the processing of various types of textiles to render them water-proof. Different methods utilize different qualities of soap: its ability to wet and penetrate the cloth fibers, its strong emulsifying powers to suspend water-

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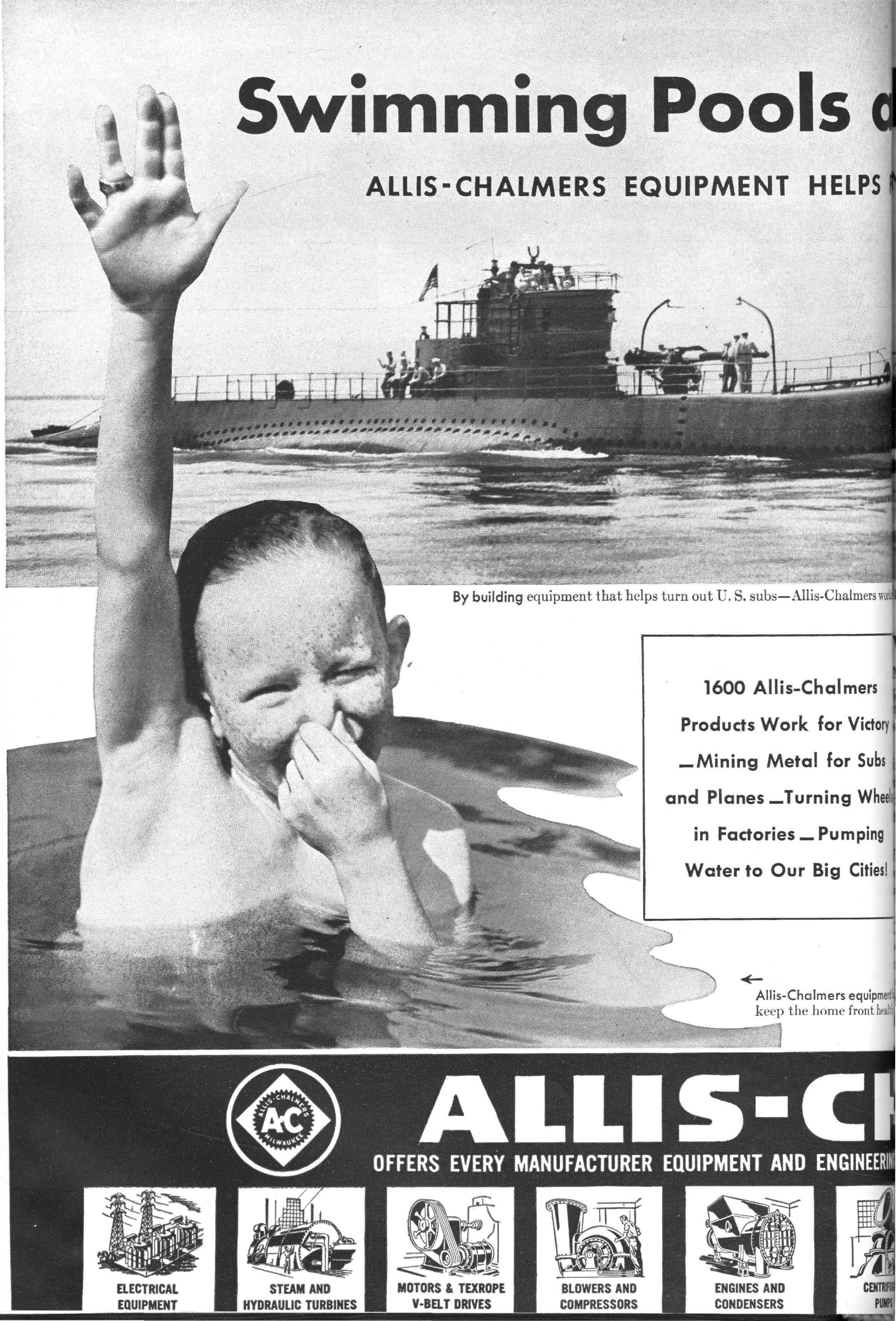
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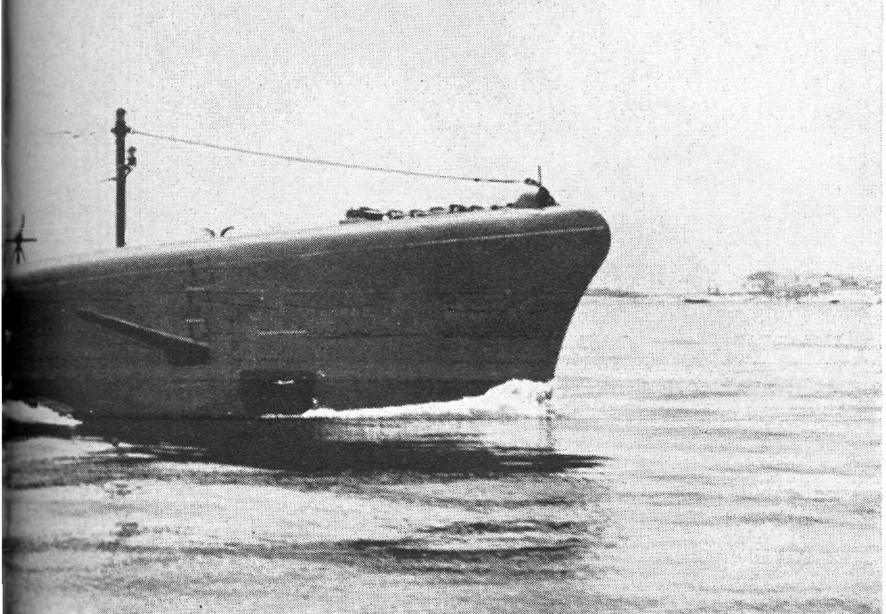

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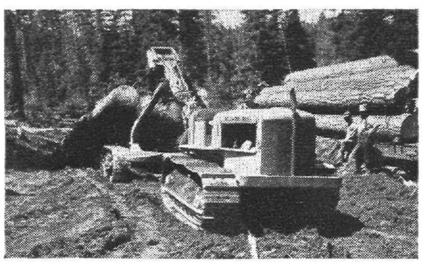

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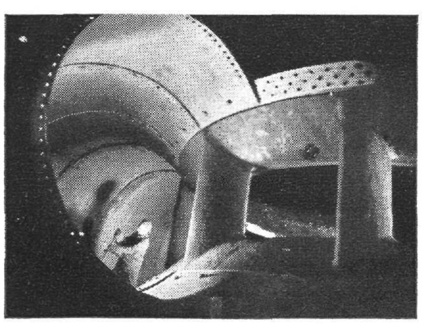
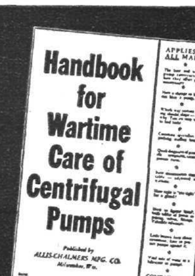


A-C equipment puts rivers to work—supplying power for the war effort!

VICTORY NEWS

Converted Carriers Aid Navy! Official Navy Photos reveal that merchant vessels are rapidly being converted into auxiliary-aircraft escort ships to protect convoys from subs and bombers. On some ships already converted a great variety of A-C equipment has been installed—including main propulsion turbines, auxiliary generating sets, condensers, centrifugal pumps, motors and control.



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New "Electro-Cooler"! Vitally needed increases in power transformer capacities can now be obtained quickly with a new system of forced-oil cooling that saves 25% in critical war materials on new transformers.

This new Allis-Chalmers cooling unit, called the "Electro-Cooler," will step up capacity of transformers already in service by about 20 to 60%.

This new unit makes the forced-oil system of cooling transformers highly practical because it is built compact, factory-assembled and factory-tested at high pressure to minimize the possibility of future maintenance. If transformer has radiator valves, the unit can be removed without draining transformer oil and parts can be replaced without delay in transformer operation.

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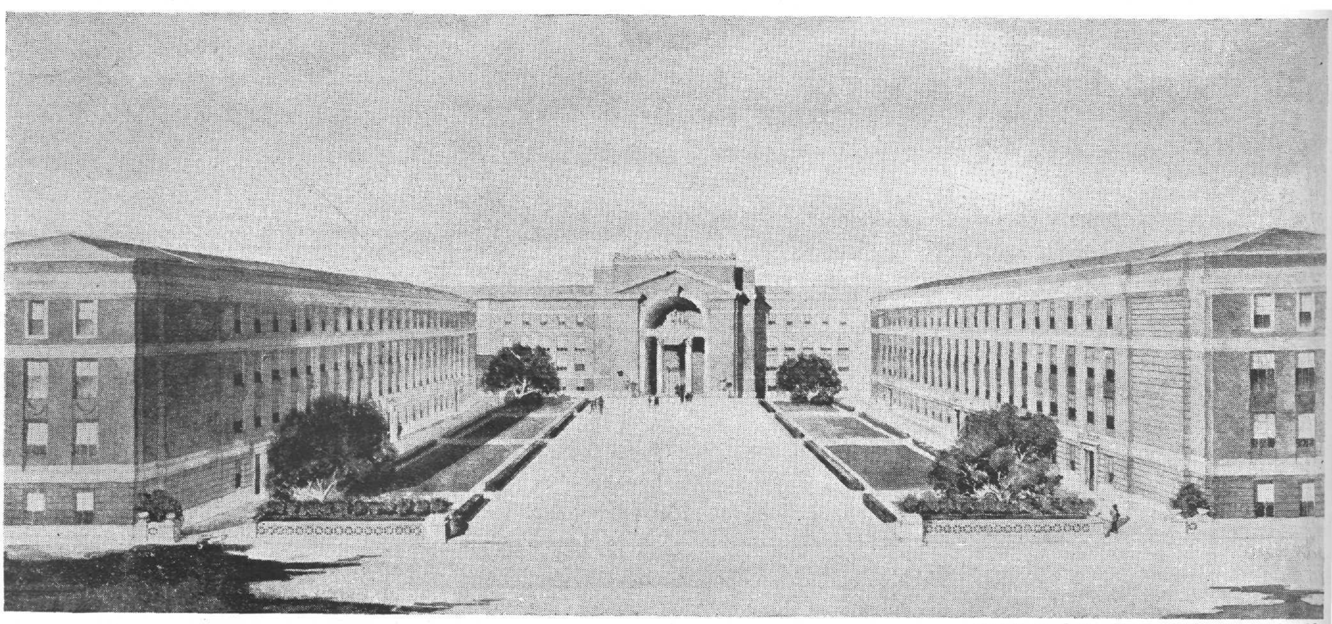
proofing substances, or its ability to react chemically with metallic salts and proteins.

Soap is playing an important part in relieving the rubber shortage. Most of the plants for the manufacture of synthetic rubber use the so-called butadiene process. This process involves the reaction of butadiene with one or more chemicals to yield the famous Buna S, Buna N, and Ameripol rubbers. In order that the chemicals react, it is necessary to emulsify them in water with various secret catalysts. The all-important emulsification is obtained by means of a special blend of soaps added to the reaction vat.

In reclaiming scrap rubber, soap is again an important factor. In this process, the old rubber, after being freed from undesirable matter such as cloth and metal inserts, is ground up with water and soap and other substances to form a milky liquid that greatly resembles the natural rubber latex as it comes from the tree. The artificial latex can be used to partially replace the natural latex.

It has been said that the degree of civilization may be measured by the quantity of soap consumed per capita. From its many and varied uses, ranging from industrial applications to hygienics, the truth of the statement becomes more and more apparent. Soap, by virtue of its singular properties, has become a most important chemical, as well as a household necessity.



—Courtesy Ohio State University Monthly

The Proposed Quadrangle Development